Computational learning theory can assess learners by computational complexity, by sample complexity (how much data is required), or by other notions of optimization.[49]

Natural language processing

Natural language processing (NLP)[50] allows programs to read, write and communicate in human languages such as English. Specific problems include speech recognition, speech synthesis, machine translation, information extraction, information retrieval and question answering.[51]

Early work, based on Noam Chomsky's generative grammar and semantic networks, had difficulty with word-sense disambiguation[f] unless restricted to small domains called "micro-worlds" (due to the common sense knowledge problem[29]). Margaret Masterman believed that it was meaning and not grammar that was the key to understanding languages, and that thesauri and not dictionaries should be the basis of computational language structure.

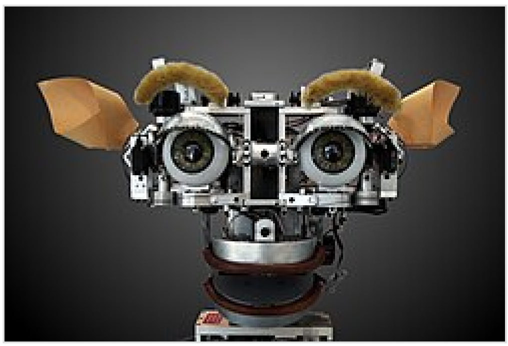
Modern deep learning techniques for NLP include word embedding (representing words, typically as vectors encoding their meaning),[52] transformers (a deep learning architecture using an attention mechanism),[53] and others.[54] In 2019, generative pre-trained transformer (or "GPT") language models began to generate coherent text,[55][56] and by 2023, these models were able to get human-level scores on the bar exam, SAT test, GRE test, and many other real-world applications.[57]

Perception

Machine perception is the ability to use input from sensors (such as cameras, microphones, wireless signals, active lidar, sonar, radar, and tactile sensors) to deduce aspects of the world. Computer vision is the ability to analyze visual input.[58]

The field includes speech recognition,[59] image classification,[60] facial recognition, object recognition,[61]object tracking,[62] and robotic perception.[63]

Social intelligence



Kismet, a robot head which was made in the 1990s; it is a machine that can recognize and simulate emotions.[64]

Affective computing is a field that comprises systems that recognize, interpret, process, or simulate human feeling, emotion, and mood.[65] For example, some virtual assistants are programmed to speak conversationally or even to banter humorously; it makes them appear more sensitive to the emotional dynamics of human interaction, or to otherwise facilitate human–computer interaction.

However, this tends to give naïve users an unrealistic conception of the intelligence of existing computer agents.[66] Moderate successes related to affective computing include textual sentiment analysis and, more recently, multimodal sentiment analysis, wherein AI classifies the effects displayed by a videotaped subject.[67]

General intelligence

A machine with artificial general intelligence should be able to solve a wide variety of problems with breadth and versatility similar to human intelligence.[68]

Techniques

AI research uses a wide variety of techniques to accomplish the goals above.[b]

Search and optimization

AI can solve many problems by intelligently searching through many possible solutions.[69] There are two very different kinds of search used in AI: state space search and local search.

State space search

State space search searches through a tree of possible states to try to find a goal state.[70] For example, planning algorithms search through trees of goals and subgoals, attempting to find a path to a target goal, a process called means-ends analysis.[71]

Simple exhaustive searches[72] are rarely sufficient for most real-world problems: the search space (the number of places to search) quickly grows to astronomical numbers. The result is a search that is too slow or never completes.[15] "Heuristics" or "rules of thumb" can help prioritize choices that are more likely to reach a goal.[73]

Adversarial search is used for game-playing programs, such as chess or Go. It searches through a tree of possible moves and countermoves, looking for a winning position.[74]

Local search

Local search uses mathematical optimization to find a solution to a problem. It begins with some form of guess and refines it incrementally.[75]

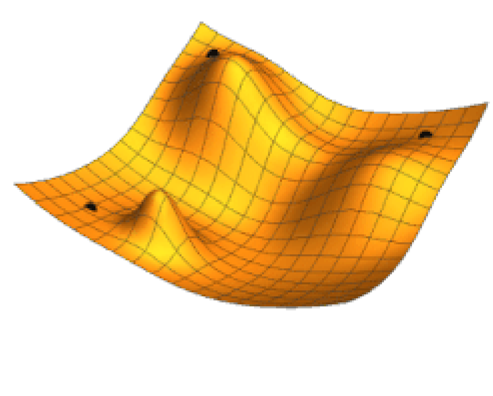


Illustration of gradient descent for 3 different starting points; two parameters (represented by the plan coordinates) are adjusted in order to minimize the loss function (the height)

Gradient descent is a type of local search that optimizes a set of numerical parameters by incrementally adjusting them to minimize a loss function. Variants of gradient descent are commonly used to train neural networks,[76] through the backpropagation algorithm.

Another type of local search is evolutionary computation, which aims to iteratively improve a set of candidate solutions by "mutating" and "recombining" them, selecting only the fittest to survive each generation.[77]

Distributed search processes can coordinate via swarm intelligence algorithms. Two popular swarm algorithms used in search are particle swarm optimization (inspired by bird flocking) and ant colony optimization

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